

SPECIFICATION

- o Amend paragraph beginning at page 1, line 11, as follows:

Fuse systems serve to detonate the main charge ('secondary' of military ~~ordnance~~ ordnance) of a munition, a cartridge, or an ordnance (collectively referred to herein as ordnance) at the desired time or location. The fuse (or fuze) plays an essential safety role of preventing accidental detonation of the ordnance, making the ~~ordnance~~ ordnance safe to handle. There are a variety of technologies used in fuse systems. The fuses considered here are "programmable": immediately prior to the ordnance being fired from a gun, timing or similar data is loaded into the fuse so that the fuse initiates detonation of the secondary charge of the ordnance at the desired time and/or location. One common approach to such a fuse system is to charge a capacitor, and then discharge it at the desired time across a thin wire to create sufficient local heating or a spark to ignite the primary explosive. On-board electronics or mechanical devices control the discharge timing. Fuses typically incorporate "g-switches" that prevent detonation until the fuse has been exposed to accelerations of a magnitude and time typically only encountered in a gun barrel. There are on-going efforts at fabricating Micro-Electrical Mechanical Switch (MEMS)-based g-switches.

- o Amend paragraph beginning at page 3, line 15, as follows:

In the following description, identical element designations in different figures represent identical elements. Additionally in the element designations, the first digit refers to the figure in which that element is first located (e.g., ~~101~~ 100 is first located in Fig. 1).

- o Amend paragraph beginning at page 3, line 21, as follows:

Almost all artillery shells, torpedoes, ~~ordnance~~ ordnance incorporate a fuse that serves to detonate the main charge ('secondary') at the desired time. The fuse plays an essential safety role of preventing accidental detonation, making the ~~ordnance~~ ordnance safe to handle. The ideal fuse would take up a negligible amount of space, is safe to handle, and ignites the main charge at the correct time. In accordance with the present invention, an ordnance fuse apparatus is disclosed that uses electrical, mechanical, and optical devices for improved safety and reliability of the fuse.

- o Amend paragraph beginning at page 3, line 28, as follows:

With reference to Fig. 1 there is shown, in accordance with the present invention, an illustrative diagram of our ordnance fuse apparatus 100, which together with explosive charge 142 are part of an ordnance to be fired and detonated. The ordnance fuse apparatus 100 is shown to include five main components including a laser and detector unit 110, an optical switch or shutter 120, a microlens 130, an explosive charge 142 and a "programmable" electronic control chip 150. Illustratively, the laser/detector unit 110 includes laser 111 and detector 114 mounted on an Indium phosphide (InP) chip 115, which connects to controller chip 150. The laser/detector unit 110 may include built-in self-test circuitry to test the operation of laser ~~111~~ 111 and pre- and post-firing position of optical switch 120.

- o Amend paragraph beginning at page 4, line 15, as follows:

In a preferred embodiment, the MEMS shutter 121 may be implemented as described in the concurrently filed patent application of D. S. Greywall entitled "MICROMECHANICAL LATCHING SWITCH," Serial No. ~~10/xxx,xxx~~ 10/766,451, which is incorporated by reference herein. It should be noted that the optical switching performed by MEMS shutter 121 may also occur by tilting a reflective element to redirect laser light to the explosive charge unit 140 rather than by moving the shutter to unblock the light (letting light pass) to explosive charge unit 140. One such tilting MEMS optical switch which may be utilized is a MEMS mirror as described in the article entitled "Monolithic MEMS optical switch with amplified out-of-plane angular motion", written by "Lopez, D.; Simon, M.E.; Pardo, F.; Aksyuk, V.; Klemens, F.; Cirelli, R.; Neilson, D.T.; Shea, H.; Sorsch, T.; Ferry, E.; Nalamasu, O.; Gammel, P.L", published in "Optical MEMs, 2002. Conference Digest. 2002 IEEE/LEOS International Conference on , 20-23 Aug. 2002, Page(s): 165 -166" on "2002 Aug. 23".

- o Amend paragraph beginning at page 5, line 1, as follows:

In this embodiment, electronic control chip 150 would receive a signal from an accelerometer (g-switch) 122 and generate a signal to the MEMS ~~locking~~ blocking mirror which would redirect the laser light from the detector 114 to the explosive charge unit 140.

- o Amend paragraph beginning at page 5, line 23, as follows:

The explosive charge unit 140 may include an explosive charge 142 alone or in combination with a Reactive Nano Technologies (RNT) foil 141 (as a primer charge). The RNT foil 142 is a highly energetic nano-metal material that is easily ignited by a focused laser. It should be noted that other types of pyrotechnic or explosive device that can be ignited by a focused laser could be substituted for the RNT foil ~~142~~ 141. When the ordnance includes an explosive charge 142, but not a RNT foil 141, the laser ~~111~~ power must be made sufficient to directly ignite the explosive charge 142. When the explosive charge unit 140 includes a RNT foil 141, the laser ~~111~~ ignites RNT foil 141, which then ignites the explosive charge 142. When a RNT foil 141 is used, it is implemented as part of the ordnance fuse apparatus 100, while the explosive charge 142 is not included as part of the ordnance fuse apparatus 100.

- o Amend paragraph beginning at page 6, line 20, as follows:

In step 303, controller 150 performs self-testing to check that the MEMS shutter 120 position is in the closed (blocking) position, preventing laser light from reaching the explosive charge unit 140. The MEMS shutter 121 position may be determined using a mechanical position sensor. If the MEMS shutter position is not correct, the procedure is aborted, in step 306, and an Abort signal is sent back to the fire control unit to prevent the ordnance from being fired. If the position is correct, then in step 304 controller 150 checks the operation of the laser ~~111~~ and detector 114, by detecting low-power pulses (<1mW) from the laser 111 which are reflected by the shutter 120 onto the detector 114. In step 305, if it is determined that the MEMS shutter position is not safe, then in step 306 an Abort signal is sent back to the fire control unit to prevent the ordnance from being fired. Note the low power laser pulses are of such a low power that they cannot ignite the explosive even if the shutter somehow were open.

- o Amend paragraph beginning at page 7, line 8, as follows:

In step 308 the ordnance is fired and the rapid ordnance acceleration causes accelerometer (g-switch) 122 to move MEMS shutter 121 to the partially armed position in step 309. In step 310, a separate sensor (e.g., a timer or shock sensor) determines when to initiate detonation. That is, the fuse may be programmed by controller 150 to detonate after a certain time from firing or there may be some other means to determine when the fuse should go off, for example another shock sensor to detect when it has hit a wall or tank, or a proximity sensor or ~~and an~~ an altimeter, etc. In step 311, the MEMS shutter enters a fully armed state. This may be accomplished by having the MEMS shutter position moved again electrically or thermally in response to a shutter control signal from controller 150. The shutter control signal is applied after a predetermined programmed time has elapsed or in response to the shock sensor signal. The ordnance is then ready to detonate and, in step 312, the laser ~~101~~ 111 power is ramped up to its maximum value. In the fully armed state step 313, the MEMS shutter 121 either unblocks or redirects the laser ~~101~~ 111 light enabling it to impact and ignite the RNT foil 141. In step 314, the ignited RNT foil 141 rapidly heats up to over 1000°C, igniting the primary explosive (or pyrotechnic) charge 142 (201 of Fig. 2). Or in an alternative design, the explosive charge unit 140 does not include RNT foil 141 and laser ~~101~~ 111 directly ignites the primary explosive charge 142.

- o Amend paragraph beginning at page 8, line 14, as follows:

Note the RNT foil 141 produces heat but no shock wave when ignited. Many ordnance ~~application~~ applications require a shock wave of expanding gas to initiate an explosive chain. In accordance with another feature, our ordnance fuse apparatus 100 may be implemented to layer the RNT foil 141 with a thin layer or coating 143 of an explosive compound, such as silver azide or lead azide, that will be ignited by the heat of the ignited RNT foil 141 and generate the shock wave needed to initiate an explosion in the primary explosive charge 142. The thin explosive layer 143 could be for example sputtered or painted onto the RNT foil 141. This approach combines the laser ignition of the RNT foil 141 with the shock wave generation utilized to initiate a conventional explosive.

- o Amend paragraph beginning at page 8, line 26, as follows:

a) In one embodiment, the MEMS unit 120 contains a movable shutter, a shutter position sensor, and an accelerometer switch. Note in its simplest embodiment, the MEMS unit 121 contains only a movable shutter. This shutter is initially in the closed position, blocking any light from the laser from reaching the RNT foil 141. When controller 150 receives data and power, the laser 111 outputs a low-power signal, which is reflected or passed by the shutter 121 onto a detector 114. When operating in low-power mode, the laser 111 intensity is set at a level that is too weak to ignite the RNT foil 141: even if the shutter 121 were to accidentally be open, the RNT foil 141 could not ignite. Signals from detector 114 and from the shutter position sensor are used to confirm correct device operation (self-test). This information is sent back by controller 150 to the fire control box along with the decoded data.

- o Amend paragraph beginning at page 9, line 8, as follows:

b) When the ordnance is fired a MEMS accelerometer 122 is irreversibly moved by the rapid acceleration: only then is the MEMS shutter 121 free to move in response to a control signal from controller 150, which is applied after the predetermined programmed time has elapsed or a signal received from a shock sensor. The ~~ordnance~~ ~~ordnance~~ fuse apparatus 100 thus cannot ignite the RNT foil 141 or explosive charge 142 unless the MEMS shutter 121 has been exposed to a sufficient acceleration for a sufficient time: The ~~ordnance~~ ~~ordnance~~ fuse apparatus 100 cannot be detonated prior to being fired.

- o Amend paragraph beginning at page 9, line 17, as follows:

c) Once the MEMS shutter 121 is in its fully armed position, the laser 111 power is ramped up to its maximum value. The laser radiation ignites the RNT foil 141, which heats up to over 1000°C, igniting the explosive charge. By separating the RNT foil 141 and explosive charge 142 from the electrical signals of controller 150 (using laser 111 light as the source of energy for ignition), our ~~ordnance~~ ~~ordnance~~ fuse apparatus 100 is immune from detonating due to electro-static discharge or electrical failure. The laser 111 acts like an opto-isolator, preventing accidental electrical ignition.